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THE INVESTIGATOR ON-BOARD AN ORBITING SPACE STATION

Colonel Ye. Khrunov, Cosmonaut

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16. Abstract The author discusses the significance of the scientific investigator in space flights. Noting that early space flights required the services primarily of pilots, he notes that there is an increasing tendency to send scientific specialists into space, and that this tendency is being increased still further by the use of orbiting space stations, primarily designed for scientific research rather than development of the flight equipment itself.

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THE INVESTIGATOR ON-BOARD AN ORBITING SPACE STATION

Colonel Ye. Khrunov, Cosmonaut

The beginning of the direct study and practical mastery of space is among the most significant scientific and technical achievements of the middle of the 20th Century. Penetration into space is a logical step in the development of mankind. Following his mastery of the tremendous land masses of the Earth, the still broader spaces of the sea, and then the ocean of air, it was unavoidable that man would assault space. /40

We can now state with full justification that space is just as important in the life of man as the oceans of water and air. Therefore, the study and mastery of space are very important for the progress of mankind, for the present and the future.

If we look at the history of science, we find that whenever man has found himself under new conditions, he has acted primarily as an investigator, studying phenomena and facts relating to many areas of knowledge. Take, for example, our countrymen -- Przheval'skiy, Miklukho-Maklaya, many courageous explorers of the Arctic and Antarctic. The first men traveling in space found themselves in the same position.

The first voyagers in the stellar ocean were men whose earlier professional training corresponded most closely to the requirements of space flight. During the first days, the only question was whether man could survive space flight, whether the new and unusual conditions would be within his capacities.

Earlier explorers also used equipment. However, the equipment which man must use to travel in space is beyond comparison. Suffice it to say that whereas earlier investigators could move on land, water and even in air at whatever speed they could achieve, space flight requires immediate achievement of escape velocity.

The cosmonauts had to understand their new equipment, to be able to control it in flight. It is hardly surprising, then, that the first Soviet and American space travelers were pilots.

Does this mean that the door to space is closed to people of non-flying professions? Of course not. Various specialists have already taken part in Soviet space flights. The crew of Voskhod included a pilot, a doctor and a scientist. Later, the Soyuz spacecraft and the Salyut orbital station were manned by people of various professions. Their interaction with other crew members was found to be quite fruitful, allowing many complex scientific problems to be solved.

With the creation of large, long-term orbiting stations with multiple crews, the question of the participation of specialists of various areas of science will be finally answered. For the present, people involved in the investigation and mastery of space must meet the task of training cosmonauts to work in this stage, of creating conditions for extensive research work in space.

Manned space flight has never been considered a goal in itself. The scientific effectiveness of each manned spacecraft has been determined primarily by the value of the information it has produced.

The possibility of sending scientific equipment and particularly human researchers into space is a tremendous achievement of modern science and technology. It is hard to think of an area of knowledge which has not been interested directly or indirectly in this work. However, only a few specialists have yet succeeded in testing their hypotheses and assumptions under space conditions, in performing the necessary experiments.

This makes it clear how well thought-out the program of each flight must be, how effectively each minute a cosmonaut spends in orbit must be used.

We are now in the second decade of the age of man in space. From the flight of Yu. Gagarin to the orbiting space station -- this is the path which Soviet astronautics has traveled in the area of manned flight. Soviet cosmonauts have completed 18 space flights, performing many complex scientific and technical experiments, testing several types of spacecraft. Experience has been accumulated in the performance of research work on board spacecraft and orbital stations; the peculiarities of this work have been determined and the required forms of preflight preparation have been learned.

What have we learned from analysis of investigations performed by cosmonauts during flights?

First of all, we have seen a clear tendency from flight to flight toward increasing the number of experiments, expanding the range of problems solved in space, encountered problems of increasing complexity. Scientific experiments have fallen into three great groups: scientific, technical and biomedical. Investigations relating to these groups are performed in all flights.

Our attention is drawn by the fact that the number of experiments performed, their ratios in the three groups, have been approximately the same in the flights of Soviet and American cosmonauts. Obviously, this is proper for the initial stage of space flight, when researchers must solve the same problems, given approximately the same capabilities.

Now let us look at the amount of time spent in cosmonaut training on direct preparation for scientific research and experiments. We find that at present some 20% of the total training time of cosmonauts is spent in this work.

Is this a lot or a little? A lot, if we keep in mind the complexity of the entire training program. But we are seeing a trend toward increasing this time quite clearly.

The number of experiments has increased significantly with the creation of orbital scientific stations. However, their crews for the present will be the same as those used in spacecraft. Only their time spent on board the station will increase. How can an increase in the number of experiments be achieved with this crew makeup? Obviously, there are several possible means. It is obviously desirable to use experienced cosmonauts, since their earlier training and experience allows them to be trained for repeated flights in shorter periods of time. The number of experiments performed on board orbital stations can be increased by preparation of reserve experiments, and also by giving assignments to the cosmonauts during the flights themselves. These will consist of slightly altered versions of /41 experiments already performed, repetition of experiments for collection of statistics or elimination of the subjective factor. Naturally, the astronauts should be familiar with the methods of performing these experiments, and the equipment on board should be sufficient for their performance.

Among such unplanned experiments we can include all types of visual observations, photography of various processes occurring in the atmosphere of the planet, and of objects on the surface of the Earth.

We can imagine the following situation. The cosmonauts photograph various sectors of the sky or individual astronomical objects through their telescope. Television is used to allow the objects they select to be observed by astronomers on the ground. They can then draw the attention of the cosmonauts to objects of interest and give them photographic assignments. This is another means of increasing the yield of scientific information from space.

During the flights of the Soyuz spacecraft, the cosmonauts could consult with specialists on the ground, coordinating changes in experimental methodology with them when necessary.

This practice, naturally, requires a high level of scientific training of the cosmonauts, masterful knowledge of the equipment on board the station, and a creative approach to the program of research and experiments. This is one difference between man and machine. This is what makes man irreplaceable in scientific research in space.

The successes achieved by cosmonauts are somewhat reminiscent of the era of great geographic discoveries. The launching of many rockets has allowed man to look at the Earth from space, to feel weightlessness, to trod on the soil of the moon, to produce a mass of information on Venus and Mars. The present day is distinguished from earlier times in that all of the discoveries of today have followed and intelligent human plan. They have been subject to scientific prediction.

Heavy orbiting space stations, used over a long period of time by several crews, are a natural development of modern astronautics.

Quite recently, such stations and spacecraft were encountered only in science fiction. But now we know how they might look in reality. Large rooms for work and rest. A variety of scientific equipment. A broad program of investigations. Continuous service in the interests of weather prediction, oceanography and navigation. Astronomical studies are performed. Information is sent regularly to computer centers on the ground, and from there to various departments and ministries interested in receiving it.

However, for some time yet, orbital space stations will continue to be scientific research laboratories. Their crews will solve problems, perform experiments, develop new methods of investigation. The organization of this work will continue to be the business of scientific research institutes, which will supply prepared experiments for the program. The task of the crew will be to conduct these experiments, to perform rapid analysis of the data produced, to make decisions concerning their statistical reliability, etc.

Of course, it is good when the author of a scientific method or hypothesis can perform the experiments himself. As yet, however, this is impossible. For example, the American investigators of the Geminii program conducted some 60 experiments of different professional structures. These experiments were performed by 15 astronauts in 10 flights.

The size of crews for orbital space stations developed up to now is also limited. However, this results primarily from the capabilities of the transport spacecraft used to deliver the crews to the space stations than the capabilities of the stations themselves.

The stations and laboratories of the next generation will apparently be capable of accommodating a large number of researchers. New, reusable transportation equipment will allow the crews to be changed regularly. How can we imagine the crew of researchers in a future orbital space station; who will be included?

Probably, the crew might include two basic groups: astronaut-operators and astronaut-researchers. The first group, obviously, will include the expedition (station) commander. The commander controls the station, its orientation, stabilization, performs docking with the space shuttle, checks to see that the flight program is performed and is responsible for it.

The flight engineers duties include testing the operation of all systems, the correctness of their functioning. In case of defects or failures, he analyzes the situation and eliminates the defects by changing individual parts of systems or switching on backup apparatus, keeps an eye on the consumption of fuel and working fluids, the reserves available in power supplies and other installations.

The navigator. His specialty is navigation of the space station, maintenance of television and radio communications.

Scientific workers: scientists, experimenters in various areas of science -- astrophysics, geophysics, geodesy, oceanography, astronomy, biology and medicine.

Thus, two or three crew members of the station will control the flight and service all systems, while the others will perform scientific research assignments.

During long space flights, a doctor must be included in the crew. It seems to us that the doctor might be given responsibility for the life support systems and testing their functioning.

The crew members of the first group will be required for all types of stations. Each member of this group should be able to replace another in the performance of his functions as concerns control of the space station and operation of its systems.

The professional composition of the second group will be selected considering the scientific and economic assignments included in the flight program. With this composition of the crew, we can "allow ourselves the luxury" of carrying narrowly specialized crew members -- meteorologists, oceanographers, astrophysicists... However, we will not be able to do without people capable of performing a range of scientific experiments prepared by scientists on the Earth.

However, even with this distribution of duties among crew members of future orbital stations, we cannot draw a sharp line between cosmonaut operators and cosmonaut researchers. Actually, all crew members will be researchers.

Obviously, the commander must study the control systems, dynamic processes and functions of operators. /42

The flight engineer will perform flight tests and development of many systems of the station, studying the convenience of their operation and performing various technical experiments.

Investigations in the area of engineering psychology, economy and reliability will fall within the range of duties of all crew members.

The navigator will also find work. The navigational equipment also requires testing, development and further improvement. This is equally true of navigation methods.

Up to now, we have been discussing assignments which can be performed on board orbiting spacecraft by investigators, and the way in which these assignments might be distributed among crew members. However, an orbiting space station is hardly a scientific research institute in the general concept of the term, is not a research vessel of the Academy of Sciences, and in fact is not even a flying laboratory. The conditions of space flight are quite unusual for research work. They place great requirements on man and research equipment. The method of investigations required here in most cases differs in principle from that used on the ground.

Beginning with the flight of Yu. A. Gagarin, we have been studying the influence of space flight factors on the human organism, studying the working ability of cosmonauts, to determine the most favorable work and rest regimen.

The results produced in flight have allowed our specialists to develop complex scientific programs for subsequent flights, to make the necessary corrections to cosmonaut training systems and to the design of equipment and instruments.

Whereas the first manned space flights answered comparatively simple questions -- how does man feel in weightlessness, is he capable of working, how rapidly does he develop new coordination of motion, specialists of space medicine are now interested in complex questions of his mental activity, carefully analyzing the work of his sense organs.

Let us take the following example. We know how important vision is for a researcher. A number of experiments were performed on the Voskhod and Soyuz spacecraft, designed to evaluate visual acuity, contrast sensitivity and visual effeciency during space flights. They showed that the reduction in visual acuity under weightless conditions does not exceed 5 to 10%. Also, some reduction in contrast sensitivity, in perception of the brightness of colors, was noted. These changes reached their greatest values during the period of adaptation of the organism of the cosmonauts to space flight conditions.

Of course, this had to be considered in developing scientific experiments, particularly those involving visual observation. Attempts were made to avoid complex experiments until adaptation of the organism of the cosmonauts to weightlessness was completed.

It is also characteristic that the cosmonauts are under high emotional stress for the first few orbits of a flight. When a spacecraft begins orbiting, many new, previously unexperienced factors "pour" onto the cosmonauts. The most important of these is weightlessness. An unaccustomed view of the Earth is seen. Attention is scattered. During this time, it is difficult to perform complex and precise experiments. /43
Therefore, they are planned for later stages.

All experiments are "played through" very carefully on the Earth. First in the laboratory, then in the training spacecraft or orbital station. The convenience of performance of the experiments is tested.

The most important experiments may be performed in a laboratory aircraft under conditions of brief weightlessness.

If an experiment requires extravehicular activity, it is worked out in advance in a low pressure chamber.

Performance of experiments in space, if they require operations or movements by the cosmonauts, is generally slower than on Earth. Once again, the villain is weightlessness. This must be considered in composing the program.

Now, a few words on scientific instruments. There are many instruments on board an orbital station. They mostly differ significantly from those with which we have become familiar in our daily practice. Their creation is a result of the hard work of many specialists.

The conditions in space place a number of special requirements on instruments. If the instruments are installed on the outer surface of the station, they must be equipped with a temperature control system, and must operate under deep vacuum conditions. All leads of instruments to sensors, traps and other receiving devices located outside the station must be carefully sealed.

On Earth, we can adjust and readjust our apparatus as long as is necessary. In flight, each minute must be used to the maximum benefit. This places a requirement of simplicity on the instruments.

An instrument must be extremely reliable. Repair of instruments during a flight can be undertaken only when absolutely necessary.

One important and rather difficult task is the recording of the scientific data produced. Proper recording of results of investigations, precision and attention often determine the value of the information. For example, a cosmonaut performs spectography of objects on the surface of the Earth. After completion of the flight and development of the film, spectra and photographs of sectors of the Earth's surface are produced. However, it is found that the time and orbit number were not entered in the spectograph before the pictures were made. This means that the value of the information produced is exactly zero, since it is too difficult to correlate the spectrogram to the terrain.

The results of scientific observations are not always recorded on photographic film. They may be recorded on an on-board tape recorder. The cosmonauts make extensive use of on-board journals as well. Some of the scientific information from the orbiting station may be transmitted directly to the Earth by telemetry. However, in all cases, the results of scientific observations must contain precise information as to where, when and under what conditions they were produced.

What we have said concerning the work of the investigator on-board an orbiting station, of course, does not exhaust the entire range of problems and difficulties of this activity. Upcoming flights will probably yield much new and interesting information.